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What caused the North America climate anomalies in 2013/14 winter?

Peitao Peng, Arun Kumar, Mingyue Chen, and Bhaskar Jha

Climate Prediction Center, NCEP/NWS/NOAA

North America experienced severe climate anomalies in the winter season of 2013/14. The anomalies are characterized with recorded warm and draught in west coast and extremely cold in the middle and east (Fig. 1). The associated circulation anomalies had a ridge off the west coast and a trough over the inner part of the land, representing a skewed polar vortex towards NA region (Fig. 2). In this study, we analyzed possible causes for the anomalies with both statistical and dynamical tools and AGCM simulations. It is found that in the observation, the seasonal mean circulation anomalies over North America was a part of wave train propagated from the jet exit region over the North Pacific (Fig. 2) . The lack of Gill-type heating-circulation in lower latitudes, however, suggests that the wave train may not be directly forced by tropical heating for the whole season. A further examination of monthly mean data suggests that the wave train was likely initiated by tropical heating in December and maintained by internal dynamics in following three months (Fig. 3). On the other hand, a set of AMIP-type experiments successfully simulated the climate anomalies in North America for the winter season. Diagnostics showed that the corresponding circulation anomalies in the model were forced by tropical SST. Major differences in circulation anomalies between model and observation are in lower latitudes, where model circulation matches well with tropical heating in Gill-type relationship. In order to see the possibility that a 4-month persistence of circulation over North America could happen without persistent external forcing, we conducted a pattern persistence analysis with the monthly mean data from reanalysis and the ensemble AMIP-type simulation data. It is found that 4-month or longer circulation persistence in that region could occur in ENSO-neutral winters, though with minor probability. In addition, contribution from recent climate trend is also analyzed.

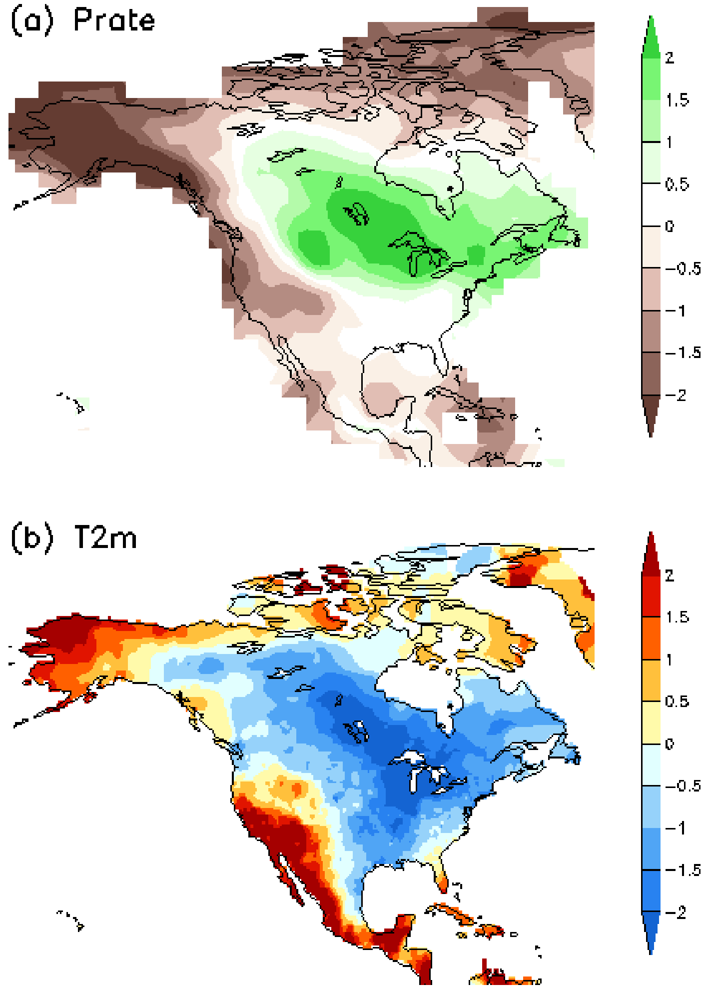

Fig. 1 Standardized seasonal mean precipitation and 2-meter temperature anomalies of 2013/14 winter (Dec-Jan-Feb-Mar). The unit is the standard deviation of the seasonal mean anomalies over the period of 1981-2010.

Correspondence to: Peitao Peng, Climate Prediction Center, NCEP/NWS/NOAA, 5830 University Research Court, College Park, MD 20740-3818; Email: Peitao.Peng@noaa.gov

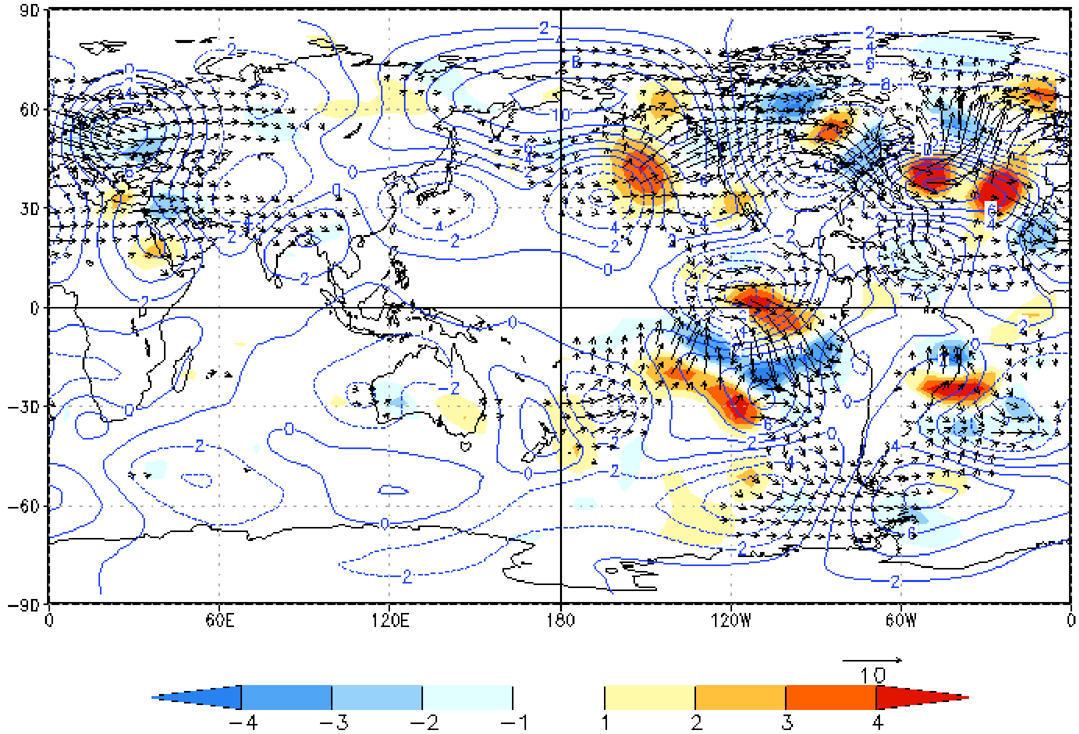

Fig. 2 200 hPa stream function anomaly (contours), wave-activity fluxes (arrows) and their divergence (shadings) for DJFM mean of 2013/14 winter. Units: 10^6 m^2 s^{-1} for stream function, m^2s^{-2} for wave activity fluxes, and m s^{-2} for divergence of wave-activity fluxes.

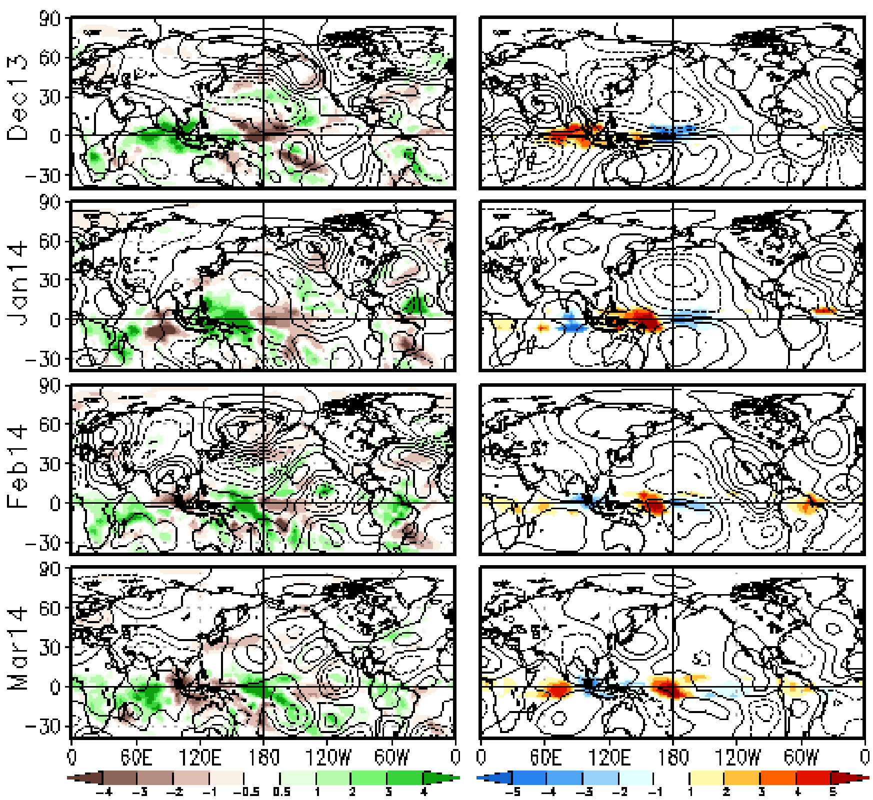

Fig. 3 Left column: Observed 200 hPa stream function (contours) and precipitation rate anomalies (shadings) for individual months of 2013/14 winter. Right column: Linear model response to tropical divergence (shadings) in a linear model with 200 hPa climatological basic state of the month. The divergence anomalies are specified with the same patterns of the precipitation rate in equatorial region. Units: 10^6 m^2s^{-1} for stream function, mm/day for precipitation rate, and 10^{-6} s^{-1} for divergence anomalies.